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STUDY AND IMPROVEMENT OF THE S-1 PHOTOEMISSIVE SURFACE.(U)
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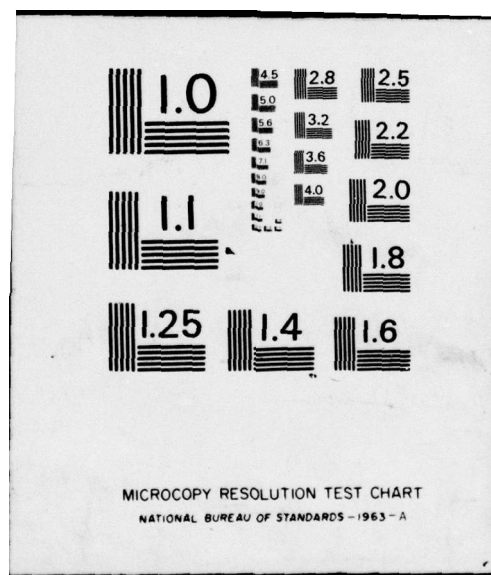
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(10th)
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FOR

STUDY AND IMPROVEMENT OF THE S-1 PHOTOEMISSIVE SURFACE, (a)

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PART I - PURPOSE

(C) Under this contract, photoelectric emission of the S-1 surface is being studied. Specific aims are:

1. Increase of white light sensitivity to $100 \mu\text{a/l}$ for 2870°K .
2. Reproducibility of processing schedules for high sensitivity cathodes.
3. Lowering of the thermionic emission to a value of 10^{-13} A/cm^2 or less.
4. Measurement of physical and optical surface properties.

PART I - GENERAL FACTUAL DATA

(U) During the month of January, twelve experimental tubes were processed. Several experiments were also undertaken to form space reflective substrates which did not always lead to completed assemblies.

PART I - DETAILED FACTUAL DATA

A. Tubes processed during the month of January

(U) Eight space reflective cathodes were prepared and formed; all were of the spherical type. Also, a large size copper oven was designed which keeps the entire substrate area at an elevated temperature of 220° to 250°C during the SiO evaporation. The quality of the SiO films on the Ag mirror is still variable. Breakup effects

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(U) at the edges of the SiO film were observed. This is not due to temperature differences because the size of the copper oven insures a fairly uniform temperature.

(U) Because the slightly less desirable reflective properties of aluminum are at the present stage a factor of secondary importance, we have decided to abandon totally the use of Ag as a mirror substrate.

(U) In six attempts, the SiO film formed well on the aluminum substrate. In contrast to the Ag substrate where usually no visible trace of the SiO film (in the thickness used here) was observed, a clear indication of the SiO deposit was observable on the aluminum. Two tubes (#5259, and #5264) resulted in good sensitivities, two more in medium ones. A computation was made to determine the thickness of the SiO deposit from the measured optical data. (See results under "B" of this report.)

B. Summary of work performed during this period

1. Preparation of the dielectric reflector

(U) The experience of the last four months have clearly indicated that the preparation of the dielectric film on an aluminum backing mirror is much more reliable and controllable than the same preparation on an Ag backing mirror. The reflective properties of aluminum are somewhat poorer than those of silver in the near infrared. A discussion of these data is given in 2. of this summary.

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(U) The preparation of the reflector is done as follows:

- a. After the usual hard glass cleaning, the Ag strip cathode connection is painted onto the glass and baked at 120°C for about 1 hour.
- b. Aluminum is evaporated in a 10^{-6} vacuum to opacity. This evaporation is completed in 7-10 seconds. A mask of approximately one-half inch in diameter shields a portion of the later cathode area which can be used for front transmission measurements.
- c. The aluminum mirror is baked at 250°C in air for two hours.
- d. SiO is evaporated from a generator-like source to the desired optical characteristics in a 10^{-6} vacuum.
- e. After deposition, the SiO deposit is washed with deionized water, isopropyl and acetone and then blown dry.

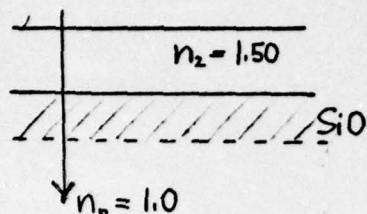
(U) During evaporation, the transmission through the glass plus SiO deposit is measured through the open hole in the mirror. At the same time, the reflection from the aluminum backing plus growing SiO deposit is measured. Both of these measurements are done with suitable monochromatic (or color) filters. The evaporation of the SiO is performed stepwise and these two optical characteristics are measured after each step.

2. Determination of the thickness of the SiO deposit

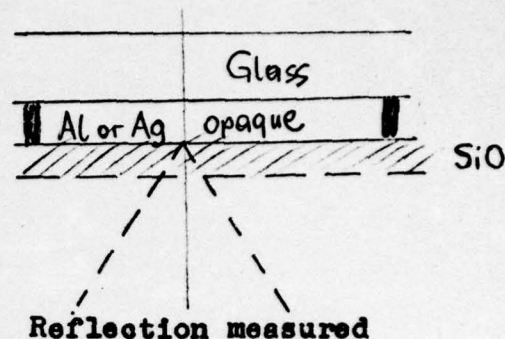
(U) If the optical constants of a film and its substrate are known, the thickness can be determined from the measured reflection and transmission.

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(U) In our case, the following two optical data are measured:



Transmission measured



Reflection measured

(U) We assume that the SiO is transparent in the red and near infrared and has a refractive index of $n_1 = 1.8$. The optical constants of the substrates Al, Ag at the wavelengths of interest are:

	<u>Al</u>	<u>Ag</u>	<u>R_{Al}</u>	<u>R_{Ag}</u>
4200Å	$n = .40$ $k = 4.00$	$n = 0.065$ $k = 2.18$	91.0%	95.6%
8000Å	$n = 1.99$ $k = 7.05$	$n = 0.11$ $k = 5.41$	86.5%	98.6%
9500Å	$n = 1.75$ $k = 8.50$	$n = 0.13$ $k = 6.48$	90.0%	98.8%

(U) The n , k values are from G. Hass, JOSA, Vol. 51, p. 719.

(U) The reflectances R are computed from the equation

$$R = \frac{(1-n_2)^2 + k_2^2}{(1+n_2)^2 + k_2^2}$$

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(U) Unfortunately, R_{A1} has a minimum around 8500Å

$$R_{8500\text{Å}} = \frac{(1.08)^2 + (7.15)^2}{(3.08)^2 + (7.15)^2} = 86.3\%$$

(U) For the reflectance of the composite Al and SiO, a more complicated formula applies

$$R = \frac{g_1^2 + (g_2^2 + h_2^2) + A \cos(2\delta_1) + B \sin(2\delta_1)}{1 + g_1^2(g_2^2 + h_2^2) + A \cos(2\delta_1) + B \sin(2\delta_1)} \quad (1)$$

(U) Here is $\delta_1 = 2\pi n_1 \frac{d_1}{\lambda}$

$$g_1 = \frac{n_0 - n_1}{n_0 + n_1}$$

$$g_2 = \frac{n_1^2 - n_2^2 - k_2^2}{(n_1 + n_2)^2 + k_2^2}$$

$$h_2 = \frac{2 n_1 k_2}{(n_1 + n_2)^2 + k_2^2}$$

$$A = 2 g_1 g_2$$

$$B = 2 g_1 h_2$$

(U) For a transparent film on a transparent substrate, this reduces to

$$R = \frac{g_1^2 + g_2^2 + 2g_1g_2 \cos(2\delta_1)}{1 + g_1^2g_2^2 + 2g_1g_2 \cos(2\delta_1)} = 1 - \text{Transmission} \quad (2)$$

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(U) If we first consider the system Glass-SiO₂, we have

$$g_1 = \frac{1 - (1.8)^2}{(2.8)^2} = -.286$$

$$g_2 = \frac{(1.8)^2 - (1.5)^2}{(3.3)^2} = .091$$

$$R = \frac{.082 + .008 - .052 \times \cos(2\phi_1)}{1 - .052 \cos(2\phi_1)}$$

(U) The maxima of R are given by $\cos(2\phi_1) = -1$ $R_{\max.} = .153$

(U) The minima of R are given by $\cos(2\phi_1) = +1$ $R_{\min.} = .04$

For $\cos(2\phi_1) = 0$ $R = .089$

(U) Assuming transparency of the SiO₂ deposit, the measured transmission would swing from 96% to 84.7% (first minimum) and back again. Expressed as percent of initial reading, we expect the transmission for the 8000Å and 9500Å line to vary from 100% to 88%.

(U) The thickness for the extreme transmission readings can now be easily computed from

$$2\phi_1 = \frac{4\pi}{\lambda} n_1 d_1 = \pi \quad R_{\max.}$$

$$2\phi_1 = \frac{4\pi}{\lambda} n_1 d_1 = 0, 2\pi \quad R_{\min.}$$

(U) We get thus: for $\lambda = 8000\text{Å}$ $d_1(R_{\max.}) = 1110\text{Å}$
 $d_1(R_{\min.}) = 2220\text{Å}$ (resp. 0Å)

for $\lambda = 9500\text{Å}$ $d_1(R_{\max.}) = 1320\text{Å}$

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(U) The values actually measured for those two lines on stepwise evaporation of SiO conform reasonably to those calculated limits of change. We have never deposited heavier layers than those corresponding to the second maximum ($2\zeta_1 = 2\pi$).

(U) For the case of the reflection on Al (or Ag) we have to use the more complicated formula (1).

$$\begin{aligned} \text{(U) For Al: } &= 8000\text{\AA} \quad g_1 = -.285 \quad R = \frac{.85 + .45 \cos(2\zeta_1) - .23 \sin(2\zeta_1)}{1.06 + .45 \cos(2\zeta_1) - .23 \sin(2\zeta_1)} \\ &n_0 = 1.0 \quad g_2 = -.785 \\ &n_1 = 1.8 \quad h_2 = .397 \\ &n_2 = 2.0 \quad A = .447 \\ &k_2 = 7.0 \quad B = -.226 \end{aligned}$$

The maxima and minima of R are given by the maxima and minima of the function.

$$\text{(U) } F(y) = ay - b \cdot \sqrt{1-y^2} \quad \text{where } y = \cos(2\zeta_1)$$

$$\text{(U) The calculation shows } y_{\text{extrema}} = \pm \frac{(a/b)^2}{1 + (a/b)^2}$$

(U) With these values for $2\zeta_1$ we get $R_{\text{min.}} = 62.5\%$. The initial reflection without film is 86.5% as shown before. Again expressed as percent of initial reading, the swing would be from 100% to 72.2% for the first and following minima.

$$\begin{aligned} \text{(U) In the specific case of our example: } \quad \sin 2\zeta_1 &= .62 \\ \cos 2\zeta_1 &= -.79 \end{aligned}$$

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(U) It follows that $2\gamma_1 = 2.48$ or $d_1 = \frac{2.48}{4\pi n_1} 8000\text{\AA} = 880\text{\AA}$ for the first minimum

(U) For 9500\AA , a similar calculation yields $d_1(\text{min.}) = 1137\text{\AA}$

(U) The reflection minima on the Al substrate occur approximately at 80% of the thickness which results in transmission minima in the glass.

(U) Again the expected variations of reflectance have been observed in actual measurements. For example:

Tube No. 5266 - Reflection 8000\AA : 100% down to 69.5%, then up again to 94%; estimated $d_1 \sim 1550\text{\AA}$.

Tube No. 5268 - Reflection 8000\AA : 100% to 75.5% then up again to 96%; estimated $d_1 \sim 1650\text{\AA}$.

(U) The expected slow change of R around the minima and maxima has also been observed.

(U) A similar computation for the Ag mirror leads to a much smaller variation of reflectance. For example, at 9500\AA , the reflectance changes only from 98.8% to 96.5% for a similar thickness. This explains the difficulties which we encountered in observation of IR reflection changes on the SiO+Ag.

(U) In the blue region, the SiO film exhibits considerable absorption (probably also a much higher refractive index), and the above given equations can no longer be used.

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3. Formation of the space reflective cathode

(C) The use of Al as the reflective mirror has allowed for a larger number of surfaces with reasonable processing performance, but sensitivities are still on the mediocre level. The two best surfaces, processed in the latter part of this period were: Tube No. 5259, W.L.: 38 μ a; 2540: 3.2 μ a/l. Tube No. 5264, W.L.: 40 μ a; 2540: 5.0 μ a/l.

(C) Tube No. 5259 was processed on a heavy Ag base. The initial transmission measurement showed a coverage of 41%. After glow discharge and two Cs-O₂ cycles, reasonable sensitivity was achieved. Very little Ag was added at the end of the process. The final reflectivity of this cathode at 9500Å was 12-15%. Other attempts with a similar processing schedule have not resulted in a good cathode.

(C) Tube No. 5264 was processed with the layer method which had also previously given reasonable results. For a description of this schedule, see Report No. 30, pgs. 6-7 and Figure 4. The final reflectivity of this cathode at 9500Å was only 3.5 - 5.5%. Several other cathodes with this processing method have resulted in lower cathodes (20-25 μ a/l).

(C) From our processing experiences and also from the thicknesses of the SiO deposits, as measured and computed according to 2.) of this report, we must attempt to work with SiO films as thin as possible and also thin the initial Ag base to achieve the desired interference effect. One cathode processed on a very thin SiO film (only 2-3% transmission change in the blue region, estimated thickness \sim 100Å) has not displayed any space reflective properties at all.

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(U) So far, a relationship between maximized absorption and photosensitivity at a specific monochromatic line has not been observed.

(U) A detailed study of the measured data of the reflective and electrical properties of the space reflective cathode and their relationship will be given in the next quarterly report.

4. Optical constants of photocathodes

(U) During this quarterly period, the addition to the computer program which covers the values for front reflection, vacuum reflection, and transmission for refractive indices from 5 to 7.5, was received through private channels.

(U) It appears that it will now be possible to get a better interpretation of the refractive index which appears to increase monotonically from the blue end of the spectrum to the infrared. It should be possible to present the results of the calculations in the next quarterly report.

(U) Also, outside of the scope of this contract, we show, for the sake of interest, several optical constants of other photocathodes tentatively arrived at.

S-10 Tube No. 835

$3900\text{\AA} : n = 2.32 \quad k = 1.0$

Thickness $d/\lambda = .11 \quad d = 430\text{\AA}$

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(U) S-20 Tube No. SS-20

5050Å : $n = 2.875$ $k = .43$

Thickness: $d/\lambda = .095$ $d = 480\text{\AA}$

but also a better fit for the red region:

11500Å : $n = 2.0$ $k = .02$

Thickness: $d/\lambda = .075$ $d = 860\text{\AA}$

This thickness results in higher refractive indices
for the blue region:

4540Å : $n = 4.62$ $k = .28$

$d/\lambda = .19$ Thickness $d = 860\text{\AA}$

S-20 Tube No. 086

4535Å : $n = 3.58$ $k = .56$

$d/\lambda = .105$ Thickness $d = 475\text{\AA}$

9450Å : $n = 2.26$ $k = .10$

$d/\lambda = .05$ Thickness $d = 470\text{\AA}$

S-9 Tube No. 103

4535Å : $n = 4.62$ $k = .82$

$d/\lambda = .10$ Thickness $d = 455\text{\AA}$

S-11 Tube No. BX3

3900Å : $n = 4.75$ $k = 1.22$

$d/\lambda = .095$ Thickness $d = 370\text{\AA}$

6000Å : $n = 3.25$ $k = .055$

$d/\lambda = .065$ Thickness $d = 390\text{\AA}$

K-Cs Surface Tube No. B-1

3900Å : $n = 4.50$ $k = 1.07$

$d/\lambda = .095$ Thickness $d = 370\text{\AA}$

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(U) The interpretation of the optical data is not unduly difficult for all other photocathodes, except the S-1, and a thickness arrived at usually fits well over the whole spectrum. This is due to the fact that none of the other photocathodes, like the S-1 does, comes close to the region $n^d/\lambda \sim 0.5$ where the interpretation becomes very difficult. The computed values agree generally well with other published data, if any.

(U) It is planned to present more complete data in a publication.

PART II - MEETINGS, CONFERENCES

(U) On November 27, 1968, Dr. H. A. Stahl from Ft. Belvoir visited these laboratories and the present status of this project was discussed.

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